FOUR INSTRUMENTS OF CONFUSION IN TEACHING PHYSICS

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The texts in physics in common use both in the East and in the West have been written to meet the eastern requirements; consequently, while many of the western colleges allow a satisfactory amount of freedom, the result, through the use of these texts, has practically been that the eastern requirements have directed the work.

These requirements have been such, at least up to the time of the recent modifications, that it has been practically impossible to meet them in any satisfactory manner in schools in which, as is the case for instance in the free high schools of Wisconsin, the subject is almost universally a required one. Even the new requirements are still so largely quantitative in their spirit that there is great room for doubt as to the advisability of attempting to prepare for college unless the doubtful practice, so commonly being adopted, of making the college preparatory an elective course is to prevail. This would mean that if pupils are to be given to any adequate extent the wider view of life and its relations, with a permanent interest in the natural phenomena about them, separate classes must be formed whose work will not count as a preparation for study in a higher school.

The results up to this time of the attempts to give to all students a general course which would meet the two purposes have been far from satisfactory from the standpoint of either life or the college. Neither interest nor ability has as a rule been developed. Even in schools having special preparatory classes the subject is elected by comparatively few, and those taking it because they really like it are much fewer still. On the other hand, the attempt to make the general class meet the requirements has resulted in very imperfect ideas coupled too often with

an actual dislike of anything related to the distorted meaning attached to the word physics.

I will illustrate by describing a typical case: A young lady with whom I am well acquainted was studying physics, not in the backwoods, but in a large school, in the shadow of what is by common consent considered a great university. The class was in charge of a well-educated young man who has since been promoted to a still better position. In conversation with the young lady I asked her to tell me in plain English the meaning of specific gravity. To make the question more concrete I used a piece of wood as an illustration, and asked what is meant when we say its specific gravity is .6. She began by giving me correctly the formal definition: "Specific gravity is the ratio, etc., etc." This was not plain, everyday, common English. Then she told me how to find specific gravity. This would have no meaning to a person who had never studied physics. She finally gave up in despair, and I suggested that the expression meant simply, in the case under consideration, that the piece of wood weighed .6 as much as the same bulk of water. Almost in astonishment she declared that she had never thought of it in that way before.

Judging from the answers to this and many similar questions received from hundreds of pupils I feel that I am safe in saying that this was a case typical of the large majority. The student was, I think, certainly up to the average in ability to comprehend physics, and she had a natural liking for the subject. At any rate she can now talk intelligently of the carburetor, throttle and needle valves, the flywheel, and the mixture of air and gas in the motor in her launch, and moreover the little engine responds more readily to her touch than it does to that of others who might be supposed to be better qualified than she in physics. She even fully appreciates the advantage of the system of pulleys used to lift the door of the boathouse. She is now a Senior in the university, but her dislike for the study is such that she has refused to elect it in her course even though she might have taken it under one of the most skilful and interesting professors in the

whole country. I do not mean to imply that the work is all poor, but the results as a whole are not what they should be.

Now in studying the general situation and especially in analyzing the means used in teaching, aside from the influence of the personality of the teacher, I cannot help concluding that the great defect lies in the misuse of four great tools of instruction, fine tools in their proper place and used at the proper time, but as used in our high schools under the conditions existing in Wisconsin, at least, turned to what may fitly be called instruments of confusion. These instruments are:

1. *Measurement.*—Undue emphasis is placed upon accurate measurement, especially with delicate and complicated apparatus. I suppose that in the case described above the pupil had been put through the usual course. There was first some brief introductory work, mainly by the teacher, with little attempt to make use of what the student already knew of the subject. Instead of some roughly approximate measurement using a familiar spring balance, a large block of some substance, and a tank of water, she was probably given a carefully adjusted balance and a small bit of some material, and required to make from ten to twenty weighings, to average the results, and to write the whole according to a prescribed form in a notebook. She was fortunate if the time of the instruction and the time of the laboratory work were not some days or even weeks apart. By the time all this was done the poor little bit of physics involved was pretty effectually lost in the maze of manipulations and averages. It may have been excellent manual-training work, but it should have been done in that department.

Laboratory work is necessary, more necessary in these days of specialization than ever before, not as a specialist's instrument in the high school, but as a means of giving clearer conceptions of the topics studied, including the supplying of information which in earlier days would have come to the pupil as a part of his own experience. Much of physics which a generation or two ago was within the observation of the pupil in its entirety is now largely obscured. For instance, in the case of the water supply. In those days the boy saw the well dug, the pump and

piping installed, and the water obtained by the application of force; now he sees only the faucet. Then, the periodical candle-making from tallow produced on the farm was a somewhat exciting event, upon the success or failure of which meant a good or poor supply of light for the winter evenings; now a button is pushed, and the light comes without further question. The chain back to the source must be supplied by the laboratory work, a large part of which still should be outside of school.

2. *The mathematical work.*—The average exercise in the texts most in use when analyzed reveals a very small amount of physics in proportion to the mathematics involved. It would make excellent material for a parallel advanced class in mathematics—either algebra or geometry, or a combination of the two. I am hoping to see the experiment tried of having such classes, conducted if possible by the teachers of physics, but such work should not take the time of or be called physics.

Physics is a quantitative study and we must use some mathematics; but in my experience both as a teacher and as an inspector I have found that the mathematics must be very simple and that round numbers or very simple fractions must generally be used if the pupil's mind is to be kept clear for the physical principle. In testing Boyle's law, for illustration, the principle will be much clearer if the confined gas be reduced to approximately a half, a third, or a quarter, than if a smaller and more closely accurate measurement be attempted.

3. *The formula.*—Over and over I find pupils using formulas and securing correct answers to problems without any definite comprehension of the meaning of the formulas, the principles and phenomena involved, or of the answer obtained. I might give many illustrations drawn from experience, but he is a fortunate and an excellent teacher who cannot secure illustrations by asking his own pupils for explanations in clear, understandable, everyday English. Teachers do not appear to realize that a formula is an instrument to save thinking and that its use very soon becomes purely mechanical, as in the case of any rule-of-thumb process. In the hands of a beginner it is a dangerous

tool if he is expected to become an intelligent, independent man rather than a mere workman.

4. *Technical terms.*—These employed to the usual extent are the most dangerous of all instruments in their possible effects. More time is wasted in science classes in mere dictionary work than one can realize unless he has had opportunity for extended observation. Instead of starting with the phenomena, the thing itself, and gradually reaching a point of understanding such that a single word may be used instead of a group to express a thought and still keep the thought in mind, the teacher is all too likely to begin with the technical word and attempt to work backward in getting at the idea. Here again is the failure to understand that the symbol is a time-saving device and that it is utterly useless without the clear idea always back of it. The accumulation of the mass of technical terms in most of our secondary science teaching is almost appalling, and it is no wonder that so many pupils emerge at the end of the study in the bewildering condition indicated by the examination tests.

Physics is a study most wonderful in its possibilities, and I sincerely hope that in the near future the work may be so modified that its usefulness will appeal to our students so strongly that we may be able to resist the demand that it be made an optional study.